NREL/JA-620-34871

THE LONG-TERM POTENTIAL OF WIND POWER IN THE UNITED STATES

Published in the November/December 2003 issue of *SOLAR TODAY*

Walter Short, Nate Blair, and Donna Heimiller, National Renewable Energy Laboratory

Please note that the figures below should be substituted for Chart 1 and Chart 2 in the printed version that follows.

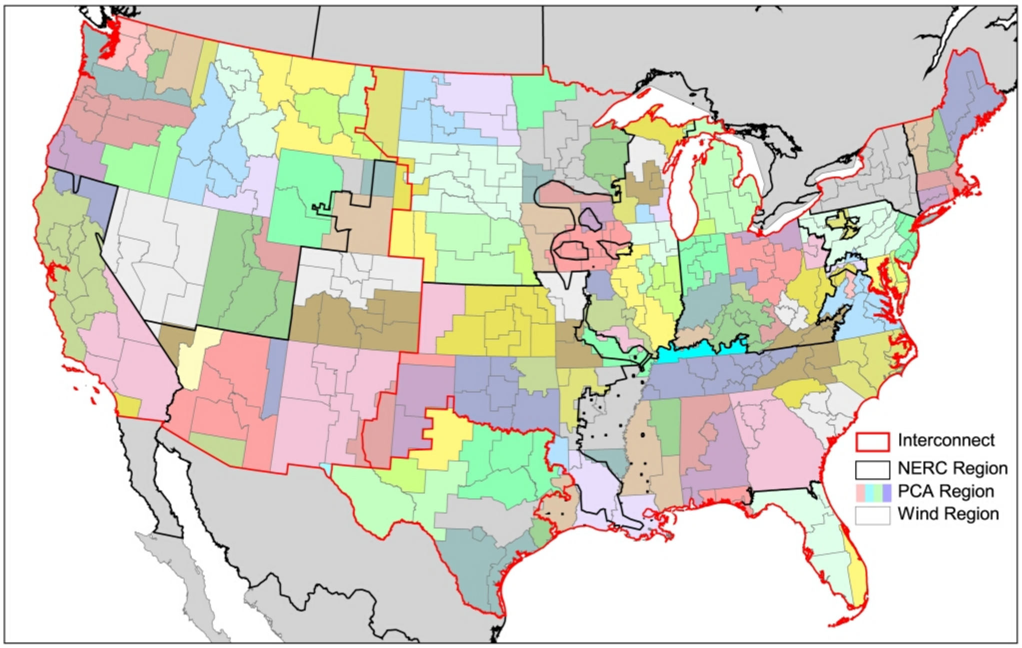

Chart 1: REGIONS WITHIN **WINDS**

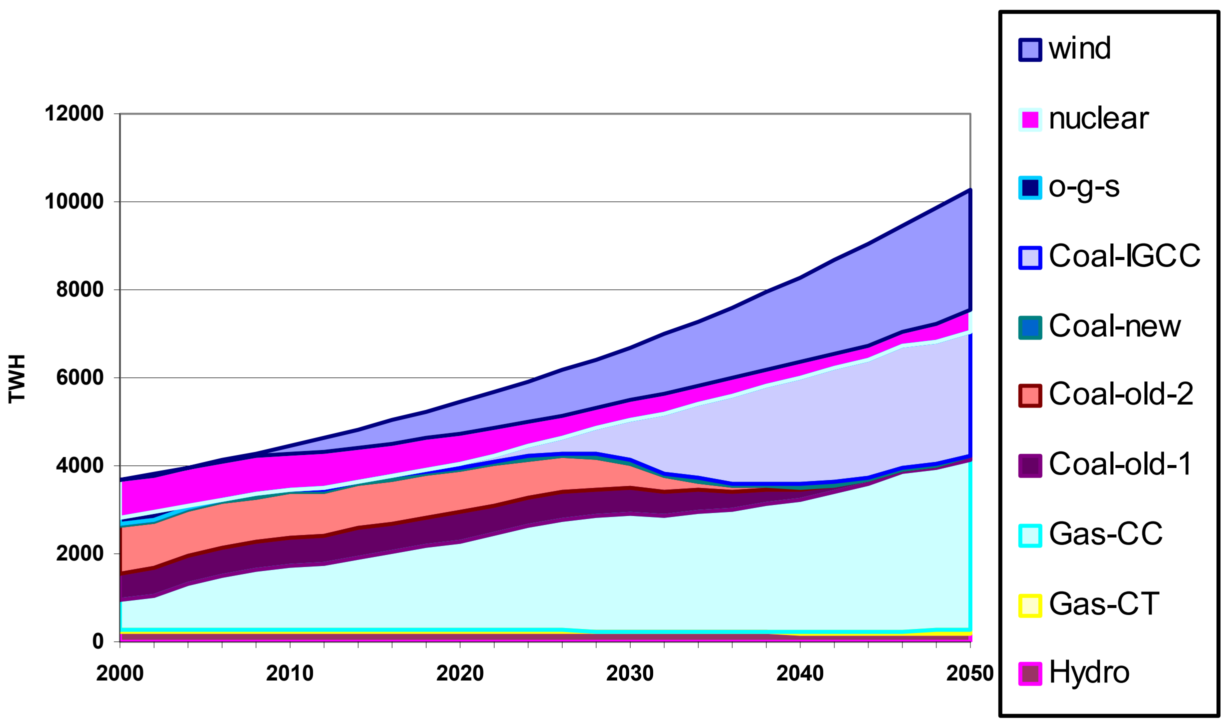

Chart 2: Base-Case Generation

The Long-Term Potential of Wind Power in the U.S.

NREL's WinDS model demonstrates that wind can be a major player in the U.S. energy market

by Walter Short and Nate Blair

Utility-scale electricity from the wind is poised for rapid growth in the United States. It's in a similar position now to coal in the 1950s and '60s, nuclear energy in the 1970s and natural gas in the 1990s. Wind promises abundant energy at relatively low prices in many U.S. locations. And although wind may not rival the abundance of coal, the "too cheap to meter" promise of nuclear energy or be as easy to site as natural gas plants, it is a cost-effective resource that eliminates fuel costs, reduces vulnerability to terrorist attacks and produces no air pollution.

In the 1950s and '60s, the U.S. built more than 150 gigawatts (GW) of coal power plants followed by more than 100 large nuclear plants in the 1970s and '80s. In the last half of the 1990s, more than 100 GWs of natural gas plants came online throughout the country. It's conceivable that wind could do the same in the coming years.

Yet there are those who question whether the drivers are in place for sustained penetration of wind into the marketplace and whether the U.S. should encourage the deployment of wind energy technologies. It's clear that the market potential for wind energy will vary across the country and over time, depending on such factors as variations in wind resources, competitive fossil technologies, transmission availability, load growth, environmental concerns and other issues. Any estimate of the national potential for wind requires a detailed examination of these factors.

To do this, the Golden, Colorado-based National Renewable Laboratory (NREL) has developed a new computer model of the market potential of wind, the Wind Deployment Systems Model (WinDS).

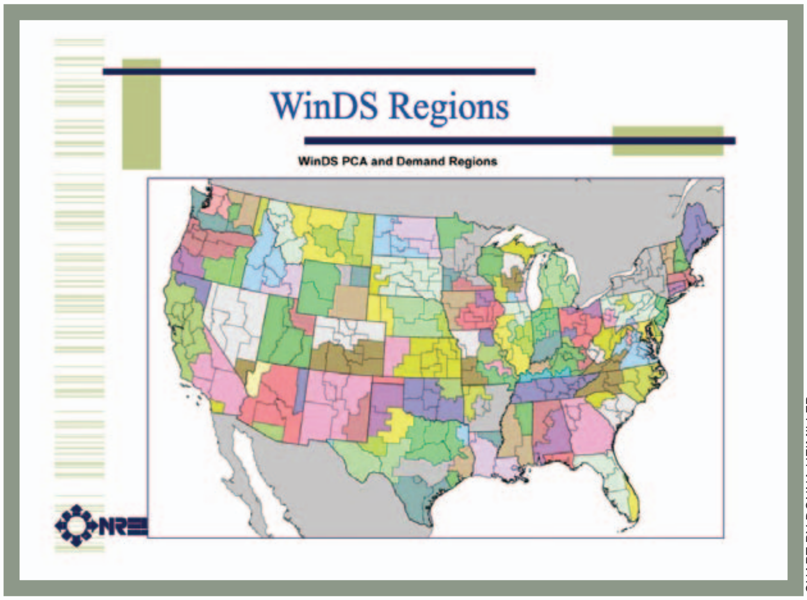

CHART BY DONNA HEIMILLER

Chart #1— Regions Within WinDS

WinDS differs from other computer models of U.S. electricity markets primarily because it uses a very detailed regional and time breakdown to examine the issues that impact wind energy.

The Structure of WinDS

WinDS models the expansion of generation and transmission capacity in the U.S. electric sector during the next 50 years. It minimizes system-wide costs of meeting loads, reserve requirements and emission constraints by building and operating new generators and transmission in each of 25 two-year periods from 2000 to 2050. It considers a wide range of generator types including natural-gas combined cycle, natural-gas combustion turbines, gas- and oil-steam generation, several coal-fired generator options, nuclear energy and hydroelectricity.

WinDS divides the U.S. into 358 wind supply regions that allow it to calculate transmission distances and the benefits of dispersed wind farms (see chart #1, this page). WinDS pits wind against conventional generators across the country. It ensures that rapid changes in load and wind generation can be followed within each of 13 North American Electric Reliability Council regions and subregions and ensures adequate capacity is available for the three major U.S. interconnections—East, West and Texas.

WinDS also examines four seasons a year and four daily time slices within each season. Using these discreet time periods not only captures the correlation between wind output and loads but also permits more accurate modeling of the use of fossil fuel generators and transmission lines.

WinDS separates the wind resource into four classes ranging from Class 3 (12 mph at 33 feet above ground) to Class 6 (15 mph). A geographic information system supplies the latest NREL wind resource data, conventional generator locations and existing transmission capabilities.

Overcoming Challenges

WinDS decides how much and what type of generation and transmission to build in each time period in order to minimize the total system cost of meeting the load and reserve requirements. In addition, WinDS includes a set of constraints and considerations related to wind that are not commonly found in national energy-market models. These considerations can be broadly classified as relating to transmission, intermittency and the siting of wind-generation facilities.

The first challenge to consider is transmission of wind-generated electricity. Within WinDS, the wind-generated electricity can be transmitted either by accessing existing lines or by building new lines. If the developer chooses to use existing lines, WinDS determines the closest existing line with remaining capacity available, builds a transmission line to access that point from the wind power plant and pays a fee for the use of the existing grid. If the grid contains some form of bottleneck that would prevent the wind power from reaching its intended load, WinDS can suggest building additional transmission lines within the grid to circumvent the problem.

The second issue is the intermittent nature of wind-generated electricity. In areas with large numbers of wind plants, the intermittency of the wind resource could result in some time periods in which the amount of wind power is inadequate to meet the power load and power reserve requirements. Other times, wind generation could exceed power load requirements. WinDS accounts for the probabilities of these impacts, taking into account the correlation in wind generated from different sites.

The third consideration is the siting of wind generation facilities. For its modeling, WinDS includes the environmental and moderate land-use exclusion scenario from a 1991 study by the Richland, Washington-based Pacific Northwest National Laboratory titled "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States." The study specifically precludes wind farm development in 50 percent of all forests, 30 percent of all agricultural lands, 10 to 20 percent of range lands, 50 percent of coastal areas and 100 percent of all wetlands and urban areas, as well as in portions of mountainous areas. In addition, WinDS notes increases in the cost of building wind farms and transmission on highly sloped terrain and in populated areas.

U.S. Wind Energy Market Potential

For the base case, the WinDS model used a range of information sources, including data on electricity loads; fossil fuel prices; wind resources; conventional plant cost, performance, sizes and locations; and fossil fuel emissions. The performance and cost of wind turbines and those of its principal competitor—natural gas—are the most significant of these input parameters.

Using data from the U.S. Department of Energy (DOE) Energy Information Administration's Annual Energy Outlook 2003, the WinDS model assumes an increase in real natural gas prices to electric utilities of approximately 2 percent per year. Consistent with the goals of the DOE wind program, this base case assumes that by 2020 the cost of wind at the best sites will be only $710 per kW (2002 dollars), and the wind plants will be operating at full capacity just over 50 percent of the time. The base case also assumes no production tax credit for wind beyond 2003.

With these assumptions, the WinDS model indicates that by 2050, wind could account for about 25 percent of all generation in the U.S. (see chart #2, this page). The model also shows tremendous growth in combined-cycle natural gas systems, with total generation growing (between 2000 and 2050) by a factor of almost 6. Finally, the model shows similar growth for integrated gasification with combined-cycle coal plants beginning to displace existing coal plants in the 2020s and also capturing a 25 percent market share by 2050.

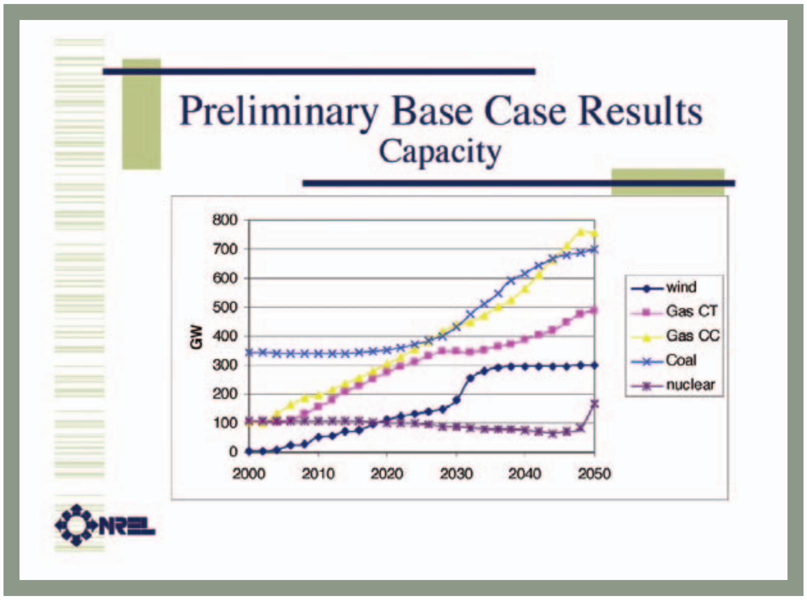

Chart #2— Base-Case Generation

There are those who question whether this is feasible given the transmission requirements, intermittency and cost of wind power. In response, it is important to point out that there are no significant resource limitations as wind has more than 8000 GW of raw potential in the U.S. Two-thirds of the wind generation in this study is delivered to markets on new transmission lines built exclusively for wind companies and paid for by the wind industry. In addition, in the latter years of the study, the cost of wind energy has fallen to the point that the wind developer can pay for all necessary backup and still be competitive with rising natural gas prices on the basis of energy savings alone. On the other hand, the penetration of wind in this base case is unlikely if the cost and performance of the wind technology does not continue to improve. Model runs made without any wind improvements or the production tax credit show no new wind installations until about 2030.

The NREL WinDS model shows that if the DOE cost goals for wind are met, wind could become a major player. If existing transmission lines are not available, the cost of building new lines dedicated to wind is not prohibitive. Similarly, the cost of wind is low enough that even when you add the expense of providing backup generation capacity to meet peak loads and all contingencies, wind is still cost-effective—even wind developed at sites with less than the best wind resource. ✪

Walter Short is a principal policy analyst at the National Renewable Energy Laboratory. Nate Blair and Donna Heimiller assisted Short in performing this research. Short can be reached at the National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado, 80439, 303.384.7368, FAX 303.384.7411, e-mail: walter_short@nrel.gov, web site: www.nrel.gov.